Production Equipment

Dispersion and Grinding Overview

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The dispersion of pigments in a final paint and coating product significantly impacts important properties of the formulation. Gloss, weather and chemical resistance, color strength and hiding power, adhesion, and durability can be enhanced or reduced depending on the nature of the dispersion. On the surface, dispersion—or the mixing of powder into a liquid by rapidly breaking apart agglomerates and uniformly distributing and wetting them—seems to be one of the simpler aspects of producing paints and coatings. If one looks deeper, however, it quickly becomes apparent that dispersion is a complex process involving a multitude of variables, all of which can affect the desired outcome and, therefore, the quality of the final formulation. In this article, we focus on the different types of equipment used to disperse pigments.

It is important to remember, though, that the choice of dispersing equipment is only one of many factors affecting the nature of the dispersion. Pigment selection is also critical. Different pigments exhibit different behaviors in different formulations, often times even if they appear to be identical. Resins exhibit different wetting properties and rheological behaviors that play a role in the dispersion process. The vehicle often acts as a stabilizing agent, too, and a balance between wetting and stabilizing capabilities must be achieved. Many times, the same binder used for pigment dispersion is used in the overall paint formulation. Yet while this seems to be a reasonable choice, it may not be due to the properties of the binder with regard to poor wettability.

The liquid base of a paint and coating is also important. Waterborne coatings will have different dispersion behaviors as compared to solvent-based formulations. Different solvents also have different dispersing properties. Surfactants must be considered as well, along with the interactions between all of the different components of a formulation.

"The most critical factor in achieving successful dispersion is the formulation," states Harry Way, technical director with Netzsch Fine Particle Technology. "The proper chemistry for wetting and stabilizing the solids results in a good product. In addition, it is fundamentally important that the components used for stabilizing the dispersion also provide the durability and adhesion required in the final product." Using consistent quality raw materials that fall within proper material specifications (particle size, pH, contamination levels, etc.) is also very critical. "The most important factor is to have good chemistry to ensure that the dispersion process can be as simple as possible, to avoid the more complicated steps like rotor stator and bead mills, and to use good quality raw materials that prevent complications like not achieving the required degree of dispersion on a consistent basis. Long periods of time required to reach the degree of dispersion are just bottlenecks in plants," Mr. Way adds.

During the process of dispersion, other factors such as seeding, air entrapment, and heat generation must be considered at all times, according to Daniyel Firestone, president of Norstone, Inc. The desired final viscosity, which is determined by the method of application of the paint (brush or spray), will also affect the dispersion. "End-use also determines the method chosen to achieve a dispersion. Flat paint, cement paints, sand filled paints, etc. do not require a fine grind, whereas an automotive or appliance finish needs a very finely dispersed product along with strength development and light fastness," Ms. Firestone adds.

The choice of dispersion equipment is undoubtedly one of the most important considerations. The extent of dispersion and reduction in particle size determines the necessary machinery and processes required for a given formulation. "The greater the surface of the pigment that is exposed and wetted, the less pigment is needed to achieve the desired color," notes Barry Cullens, laboratory manager with Hockmeyer Equipment Corporation. Ideally, dispersion will result in the surface of all pigment particles, which are identical in size, being completely coated by the liquid. This goal is nearly impossible to achieve, so a more practical goal is to produce a narrow particle size distribution and limit the number of larger agglomerates as much as possible.

There are three types of dispersion equipment commonly used today in the paint and coatings industry. Desired fineness of grind (FOG) and/or color development determine the types of dispersion equipment that must be used. High speed dispersers (HSDs) mix the initial pigment powder with the liquid, forming the "re-mix." For a few paints and coatings, the level of dispersion achieved with this machinery is adequate and no further processing is required. Many formulations today, however, require much finer particle sizes and therefore additional dispersion is necessary. Rotor-stator mixers, which afford higher shear, can be used if a somewhat finer particle size is needed. Media mills, which come in many different shapes and sizes, are utilized when very fine particle sizes and/or maximum color development are required.

When evaluating dispersion equipment, the dispersion energy required to achieve the desired level of mixing must be considered. Dispersion energy is the energy available for dispersion. Pigments that are difficult to wet will require greater dispersion energy. However, it is critical to note that dispersion energy does not necessarily correlate with the energy consumption of the equipment. Rheology and viscosity properties of the materials in the disperser and the method of addition of materials must be considered when determining the true dispersion energy of any piece of machinery.

High Speed Dispersers

High speed dispersers are the simplest type of disperser. They are generally used to introduce the pigment into the dispersion system and provide the first level of particle size reduction. "The HSDs will make a homogeneous mix of the materials and break any agglomerates into individual particles," says Glenn Vice, vice president of technology with Littleford Day. Depending on the pigment, HSDs may also provide some particle breakdown as well.

Photo courtesy of Myers Engineering.

For HDSs, a disc-type blade mounted at the end of a mixing shaft rotates at high speed. The spinning blade creates a suction that pulls in the solids and liquids, creating a vortex above and below the disc. As the liquid/solid mix enters the vortices, the horsepower of the machine is transferred to the mixture, creating a series of horizontal layers. The shear force created by the rotating blade causes the layers to be instantly accelerated outward toward the wall of the tank. "The turbulent flow created by the disc impeller puts the materials into solution, and the zones of laminar flow around the impeller cause the

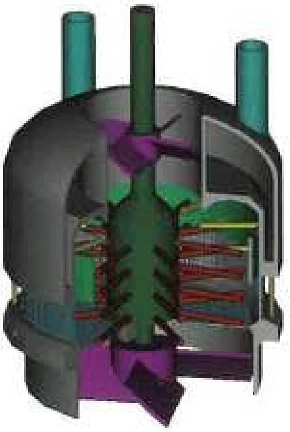


Photo courtesy of Hockmeyer Equipment Corp.

materials to smear across each other as layers moving at different speeds, causing finer deagglomeration," explains Steve Guntner, national sales manager with Myers Engineering.

There are several different types of dispersers, including single speed, two speed, and variable speed mixing shafts, but most used in the paint and coatings industry are of a single shaft, variable speed configuration. The variable speed drive most popular today is an electronic type using a variable frequency inverter. These electronic drives have become cost effective, (since they cost less to maintain and operate), are quieter in the plant, and offer the user the opportunity to monitor and/or control the mixer and process parameters, according to Mr. Guntner.

Dispersers are typically either mounted on a tank with the blade fixed in one position, or on a hydraulic powered hoist so that they can be raised and lowered and the vertical blade position adjusted. These mixers can also be moved from one tank to another, with up to four mix tanks used in a mezzanine if they are properly positioned. The type of formulation can determine the mounting of the disperser. "The move in water-based paints is to larger and larger batch sizes, requiring stationary mix tanks and large horsepower dispersers to serve them," states Mr. Guntner.

In dual or triple shaft mixers, the disperser can be put in combination with a secondary low speed sweep and/or an intermediate speed impeller to accomplish a wider range of mixing operations. In the paint and coatings industry, the low speed sweep is used to prevent buildup of material on the inside wall of a mix tank and act as a mass mover of material from the outer edges back toward the high speed impeller.

Blades for high speed dispersers also vary. Open saw tooth types are very popular due to their low cost and ease of cleaning. They also come in a wide range of tooth designs. More aggressive blades with larger teeth create increased turbulent flow, but shear decreases as a consequence. Ring-type blades are more expensive and consume more horsepower, but run at higher tip speeds and create more shear. A recent advancement in blade technology has been the development of abrasion-resistant plastic impellers for dispersing abrasive pigments such as titanium dioxide and ion oxides, according to Ms. Firestone.

The horsepower of a disperser is related to the disc diameter and anticipated loading that will be created at a given speed. Horsepower increases as disc size increases, but tank diameter and batch size, as well as the rheological behavior, viscosity, and density of the dispersion are also important in determining the true energy available for transfer. "Typically, maximum dispersion should be reached for optimized processes and formulations in 20–30 minutes," notes George Murphy, vice president of sales and marketing with Hockmeyer Equipment Corporation. Optimization includes choosing the appropriate tank geometry, blade-to-tank ratio, and blade speed; determining how and when ingredients should be added; and having the proper formulation. "Overall, the use of low power input, rapid distribution of the input power, and good contact flow among the phases will result in efficient mixing. Poor design and planning can waste power. As a result, high horsepower will not necessarily mean good mixing," says Mr. Murphy.

Mr. Cullens adds that the method of ingredient addition is critical. "About 70% of dispersion comes from particle-to-particle collisions in the tank, and only 30% from contact with the blade. There is a zone around the blade—approximately four inches all the way around—where these particle-particle interactions occur. Many people add all of the liquid at once, and it ends up over-vortexing and not in the critical zone near the blade. Low viscosity batches usually result in mixing instead of dispersion because operators are unable to reach dispersion speeds (5200 to 5600 fpm) because of the low viscosity material vortexing right out of the tank. Just enough liquid should be used initially so that the powder/solids concentration is low enough for batch movement and high enough for immediate particle-to-particle contact once the particles leave the blade. Once the dispersion starts the viscosity will build very fast and additional liquids can be added to accommodate this build in viscosity from increased surface area of the pigment."

Photo courtesy of Premier Mill Operation, SPX Process Equipment.

The advantage of the high speed disperser is that it is a cost effective and durable piece of equipment that is easy to work on and has minimal wear parts, according to Mr. Guntner. "Replacing the dispersion blade regularly is the only real requirement to maintain a level of performance," he comments. In addition, usually the mix time is relatively short and cleaning time is moderate with HSDs, according to Mr. Vice.

One major limitation is the product rheology dependence of HSDs. Mixtures that are too thick will not move freely and will therefore not be properly dispersed. According to Mr. Way, additional limitations include the time it takes to load the raw materials and the energy required to run the machine. A tremendous amount of heat is generated in the liquid that can cause problems with some formulations as well. Many try to compensate by adding the raw materials faster, but this often—especially with larger HSD machines—causes huge chunks of material to be dropped into the tank. As a result, additional time is required waiting for these clumps of solids to slowly wet out and then disperse.

Rotor-Stator Mixers

If great enough shear cannot be achieved with a high speed disperser, a rotor-stator mixer may be used. In rotor-stator mixers, the rotor lies within a stationary slotted stator. They can be used in both batch and continuous production. However, batch sizes above 1000 gallons are typically not effectively mixed with this type of dispersion equipment. In-line rotor-stator mixers provide recirculation of liquid back to the feed tank, allowing for further processing until the desired particle size is achieved. Because they do not contain any media, rotor-stator mixers are easy to clean. In some cases, the use of a more expensive media mill can be avoided with the use of an in-line rotor-stator mixer.

Media Mills

Many companies do not use rotor-stator mixers if they need more finely sized particles than these mixers and HSDs can provide. Instead, they achieve smaller sizes with media mills, which actually grind the particles. In these cases, tightly bound agglomerates that have been externally coated only require a stronger mechanical force to break them apart. Both vertical and horizontal media mills, which are also referred to as basket mills, are available in many different shapes and sizes. Typical bead mills use larger beads on the order of 1 to 2 millimeters in diameter. As the demand for finer particle size increases, however, many mills are now using much smaller grinding media (below 0.5 mm) to achieve very fine particle dispersions, according to Mr. Way.

In a horizontal media mill, the heated/cooled grinding chamber contains an agitator or milling shaft, round beads, and a low viscosity diluent. The liquid/solid formulation is pumped through the fluidized horizontal media at a controlled rate, and the solid particles are broken down or reduced in size and finely dispersed throughout the liquids. The product is separated from the grinding media via a screening device. "This wet milling process requires a stable liquid formulation," notes Stewart Rissley, national sales manager—Premier Mill Operation with SPX Process Equipment. "The formulation must be homogenous and not experience any settling or separation of solids from the liquid before the grinding takes place."

Factors that affect horizontal-milling operations include the size, specific gravity, and percent load of the grinding media; the disc shape and rotating surface area; milling shaft speed; temperature, pressure, and quality of the formulation; product throughput; and horsepower consumption, according to Mr. Rissley. Multiple passes of the product through the mill chamber may be required to achieve the desired product performance. However, a single pass process is typical.

The complexity of media mill systems is a limitation. Much more operator training is required to achieve optimal dispersion performance with this type of equipment. In addition, there are a number or parts that wear and need replacement frequently. Cleaning is also much more complicated and often requires the use of large amounts of solvents.

A more recent advancement in media mill technology is the immersion or basket mill. These media mills are located at the end of a shaft that is inserted into the tank, similar to the way an HSD is operated. The process in general is simpler and more attractive for operations that involve frequent changes of color, because cleanup is much easier. The need for extensive operator training and maintenance is also reduced with this technology.

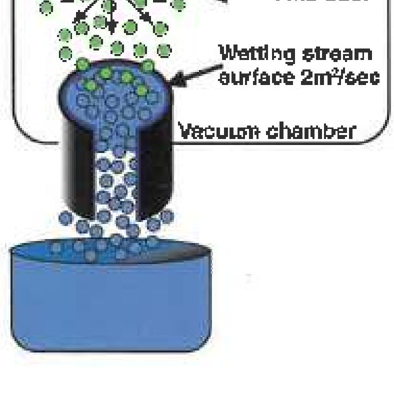


Figure 1—Basic dispersion principle. *(Courtesy of Netzsch Fine Particle Technology)*

"The introduction of the basket mill to the market has led to improvements in batch times, finished product yield, particle size distribution, and overall milling performance," asserts Mr. Guntner. "With the basket mill, milling is a function of time as opposed to being a function of the discreet pass used in either vertical or horizontal throughput-style mills. This allows the operator and chemist to check performance at regular intervals and even make minor additions or corrections during the milling operation," he adds. However, localized heat buildup and the inability to completely disperse more viscous systems are limitations of these grinding operations in some cases.

Improvements in basket mill technology include the addition of impellers or augers that pump material into the basket containing the grinding media, as well as pull it back out. These systems constantly recirculate the material and result in a more even particle distribution, smaller standard deviation, and better color.

Myers Engineering manufactures a dual shaft basket mill, the M850 series, with a mill chamber shaft and a secondary batch agitator. "The dual shaft design allows the operator to run the mill chamber shaft at optimal speed, keeping the grinding beads agitated while controlling the flow pattern in the tank with the secondary batch agitator," Mr. Guntner explains. He adds that one distinguishing feature of the Myers basket mill is the cooling shroud surrounding the mill chamber, which works to cool the product during the milling operation without the need for a jacketed mix tank.

The Premier Submersible Mill (PSM) from SPX Process Equipment consists of a media mill and dual high speed impellers in one machine. Both mixing and grinding are provided simultaneously, with the milling energy and batch circulation independently controlled. Fine dispersion is achieved in the milling chamber, where grinding media are accelerated by a rotating pin-type agitator mounted on a milling shaft. Two high flow impellers blend the product, constantly recirculating it through the basket mill, which achieves uniform dispersion throughout the entire batch. The centrifugal force of media agitation causes the flow through the milling chamber and also reduces hydraulic packing and nearly eliminates cavitation forces, according to Mr. Rissley.

"Overall, this design enables the use of the basket mill with a much wider range of product viscosities. The impellers make it possible to use the basket mill in much larger tanks as well. It also provides consistent temperature control and uniform particle size. Because the impellers are controlled by a separate variable speed drive, the pre-mix step and the grinding step can all take place in one tank, significantly reducing the costs of these operations," Mr. Rissley states. SPX also offers its NAVIGATOR computer monitoring and process control system with the PSM, allowing for automatic control of the equipment based on set product temperature and motor percent loads.

Hockmeyer's HSD Immersion Mill consists of a highly polished, water-cooled, submersible basket with side and bottom screens and upper and lower draft tubes. Within the basket is a rotating hub with pegs and a removable counter-peg assembly. Top and bottom pumping impellers work together to enhance the flow of the dispersion through the bead field in the basket. A blade in the lower draft tube focuses the suction of slurry exclusively from the mill's upper level. "Bypass" through the side screen is greatly diminished as a greater percentage of slurry is drawn deeper into the bead field or high energy zone before reaching the side or bottom screen discharge.

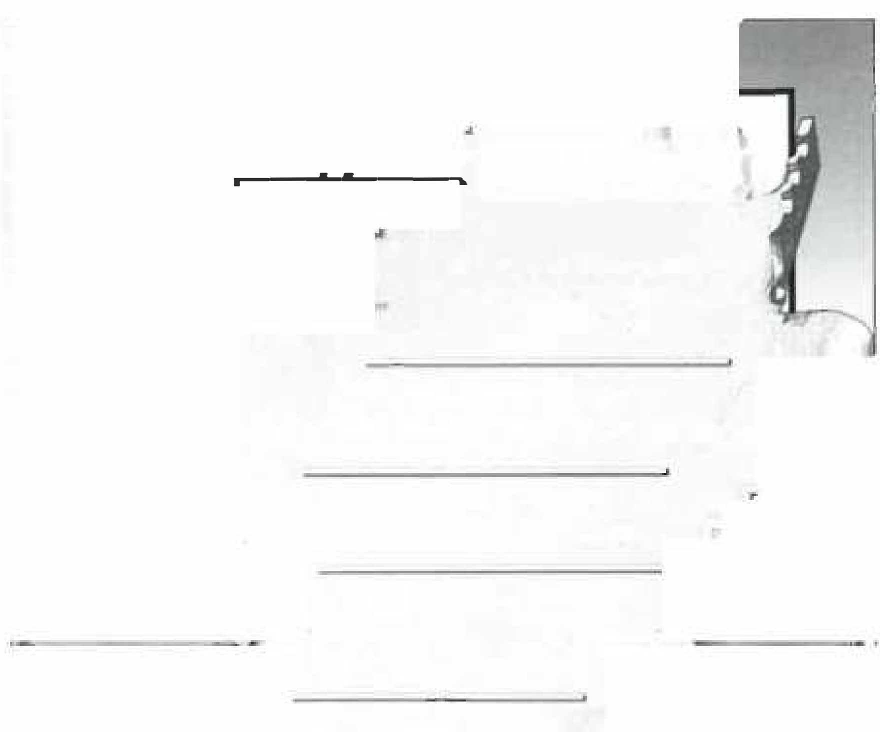
"The rapid, uniform flow of slurry drawn down through the top and outward toward the bottom of the mill increases batch throughput rate by 50%," says Mr. Murphy. "Performance is increased 20% more when a top propeller is mounted within the draft tube above the bead field to force feed the mill when viscosities are above 15,000 cps," he continues. The machine is designed for use in multiple sized tanks with various capacities and can reduce process time by an average of 30–300%. It is compatible with a wide range of media sizes and product viscosities as well. The Auto Process II control center enables the operator to run the machine on autopilot or manual control. Combination with dual and triple shaft mixers is also possible, allowing for complete processing in one tank.

With the addition of the Immersion Mill into a triple shaft configuration—with one shaft being a dispersion blade, the second shaft being a helical sweep blade, and the third shaft being the Immersion Mill—even inks that are typically formulated for 3Roll mills can be dispersed from start to finish in the same tank, according to Mr. Cullens. "After an acceptable pre-dispersion has been reached, the milling process can be started. With the auger in the upper draft tube of the mill chamber forcing the paste into the mill and the helical sweep blade feeding the auger, three roll formulations are no problem."

The most recent development in dispersion equipment may ultimately eliminate the need for high speed dispersers and media mills altogether. Based on an understanding of the micron-level forces at work during the mixing process, the PSI-Mix (Ψ-Mix©) from Netzsch Fine Particle Technology dramatically reduces mixing times using a fraction of the floor space and a minimal amount of energy.

"Ideal dispersion is achieved when fine powders come into contact with a large liquid surface under low shear. *Figure* 1 portrays the general principle. Attempts at improving industrial mixers have been self-defeating because they fail to satisfy these ideal conditions," Mr. Way explains. Rather than slowing the powder loading, the PSI-Mix dispersion equipment pre-disperses the dry powder particles prior to wetting in a vacuum chamber. Another key to the technology's success is its ability to create a significant wetting surface so that the particles come in contact with the wetted surface instantly, instead of being allowed to cake up in lumps. Air trapped between particles, which prevents further hydraulic penetration and thus dispersion, is forced from small agglomerates by a controlled negative-to-positive pressure gradient.

"By pre-dispersing the powder particles in the dry state and increasing the availability of a liquid surface



area through a vacuum eductor system, the rapid loading of powders can be sustained in an enclosed, environmentally safe process," says Mr. Way. PSI-Mix's production capacity is typically seven tons, or 10-cubic meters, of dry solids per hour. The fully automated process can be used for batch sizes of 55 to 5000 gallons, or work in a continuous process to produce homogenous products with a mix viscosity as high as toothpaste. "Mixing time is reduced by 90% compared to traditional methods. As a result, fewer machines, less floor space, and less energy are required to consistently produce the same quantity of high quality product," adds Mr. Way.

Netzsch is just introducing the PSI-Mix system to the marketplace now and it is expected by many to receive significant interest from the paint and coatings industry. Other technologies are being considered as well. Aside from trying to find new ways to increase throughput, attention has begun to focus on decreasing particle sizes down to the nano range. "Nanotechnology has commanded increasing interest in a number of industries, and paints and coatings are no exception," Mr. Cullens says. "Developing equipment to make smaller and smaller particles that can be uniformly dispersed and exhibit desired properties is one of the next steps for us." According to Ms. Firestone, the use of sound for grinding is a technology that has been considered, but remains "on the drawing board" at this point.

In the meantime, paint and coating producers have access to a wide variety of dispersion equipment. Thoughtful evaluation of these different types of machines is absolutely necessary when developing a new product. Proper selection of the appropriate dispersion equipment, along with consideration of the dispersion process, formulation components, and raw material quality, will enable paint and coating manufacturers to consistently produce high quality products that exhibit the appearance, durability, and stability desired. CT